Mobilise Your City

Topic guide

Transport modelling for mobility planning

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ECF European Cyclists' Federation

Global Partnership for Informal Transportation

ITDP Institute for Transportation & Development Policy

PLATFORMA Local & Regional International Action

SSATP Africa Transport Policy Program

TRUFI Association

UCLG United Cities and Local Governments

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Introduction

Transport modelling for mobility planning

This Topic Guide focuses on macrosimulation modelling that is relevant for large-scale mobility planning (city, urban area, region). It is not applicable to lower levels (e.g. mesoscopic or microscopic).

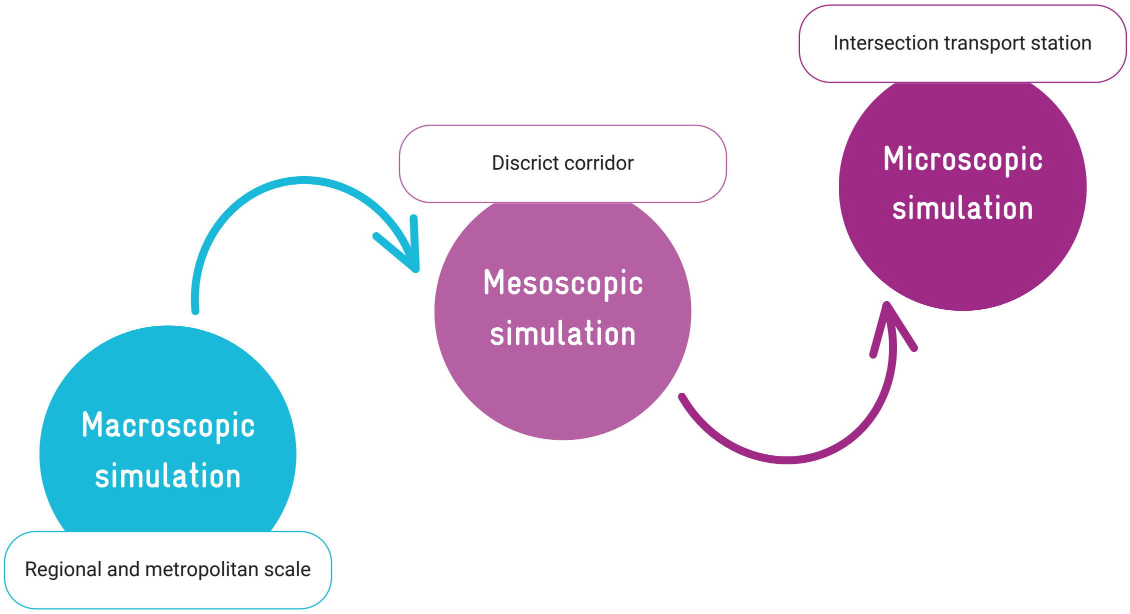


Figure 1. Types of simulation modelling and their scale application

The MobiliseYourCity Partnership

Launched at COP21 in Paris, the MobiliseYourCity Partnership is a leading global Partnership for sustainable mobility of nearly 100 partners, including 69 member cities and 15 member countries. It is jointly co-financed by the European Commission's Directorate-General for International Partnerships (DG INTPA), the German Federal Ministry for Economic Cooperation and Development (BMZ), the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), the Agence Française de Développement (AFD), the French Facility for Global Environment (FFEM), and the French Ministry of Ecological Transition (MTE). The Partnership is implemented by AFD, GIZ, ADEME, Cerema, CODATU, EBRD, KFW, and Wuppertal Institute.

With 40 million euros to support technical assistance and project preparation in 39 cities and 8 countries, the first projects completed in 2019 have mobilised 1,296 million euros for concrete sustainable mobility projects.

General approach

This topic guide aims to support practitioners (local authorities, mobility experts, consultants, and international development officials) in deciding the best solution to implement transport modelling when preparing a Sustainable Urban Mobility Plan (SUMP). Desk review and the experience of some MobiliseYourCity city members constitute the basis of the content presented. This topic guide provides insights into transport modelling and its pertinence and suggests a step-by-step guide to integrate this analysis tool when preparing a SUMP. Accordingly, the ambition of this document is not to provide ready-to-use solutions that others could replicate in every context. **This topic guide aims to propose a methodology of reflection and a set of questions to ask oneself to build a coherent, realistic, and locally-based transport model, if needed.** The document has three different sections:

- A section answering the question of **what is a transport model**? By focusing on the objectives of transport modelling in SUMPs formulation.
- A section focusing on **why to develop a transport model?**, defining the main elements to consider when deciding whether a transport model is crucial or not for the planning process.
- A section describing **the types of transport models** that can be used to support the development of a SUMP.
- The last section focuses on **how to develop a transport model for SUMP development**, detailing tools and instruments to mobilise at various steps along the SUMP cycle.

What is a transport model?

Transport modelling has been a widely spread approach for decades to help policymakers design transport projects and strategies that best fit present and future needs and mobility behaviours. Transport models are the mathematical representation of the functioning of mobility systems in a determined geographical area, being a simulation of reality. The models require a large volume of such data as input, including data on mobility patterns, urban planning and economic activity, socio-demographics and supply of transport systems. These data include supply (road network, public transport systems, public spaces) and demand factors (mobility patterns, public and private transport passengers). **A transport model relies on existing knowledge of the transport supply, the transport demand and how the two interact (e.g., users' preference according to mode, price and travelling time). Based on their relation, transport supply and demand can be assessed under hypo-thetical conditions.**

Parameters of a modelled scenario generally include the distribution of the population and jobs over the territory and the transport supply – routes, headway, running time/commercial speed.

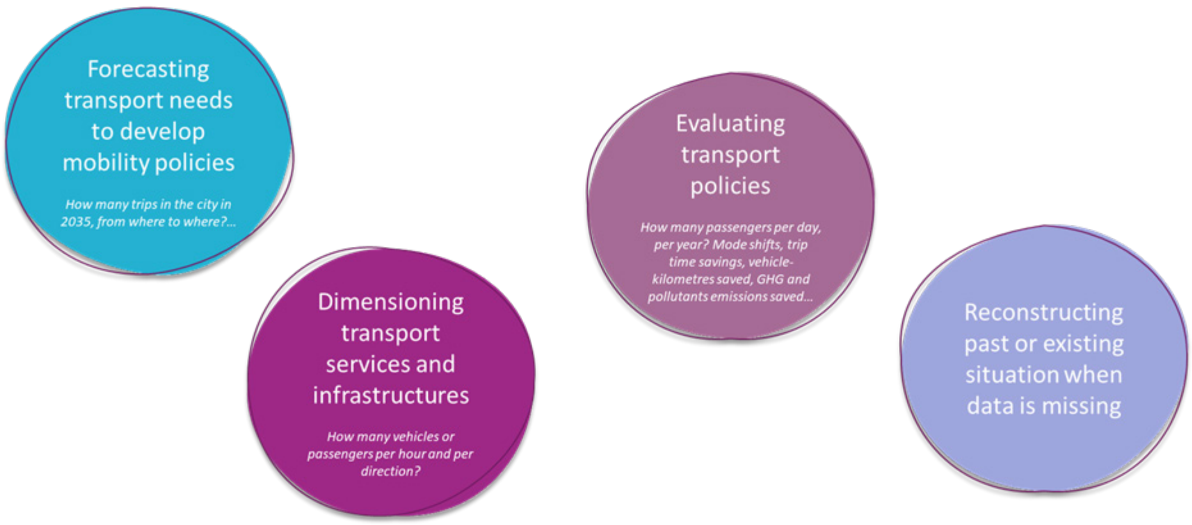


Figure 2. Objectives of transport modelling

Models generally rely on transformed data inputs along with complex algorithms and calculations to provide output data. The modelling process then consumes quite a large amount of data (distribution of population and job, public transport routes, level of service per mode, passenger flows across the urban area) and requires relatively long work to be established and become fully operational (about two months).

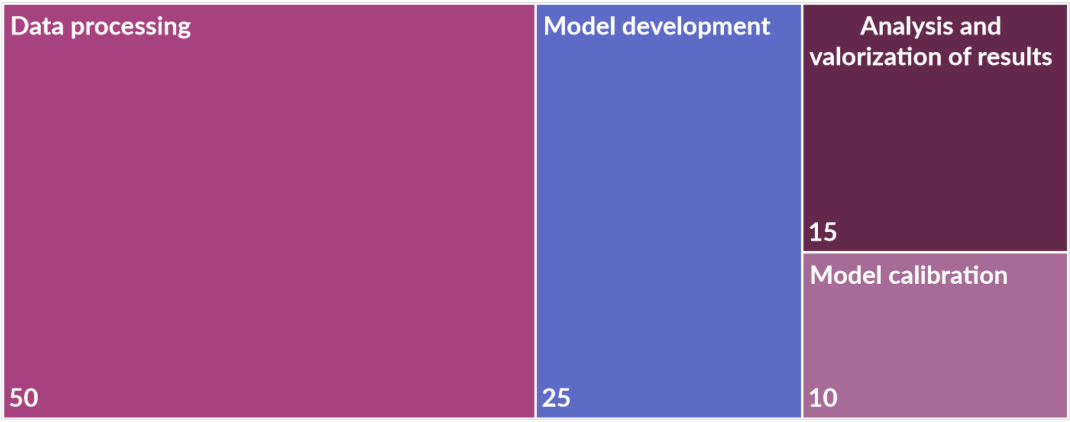
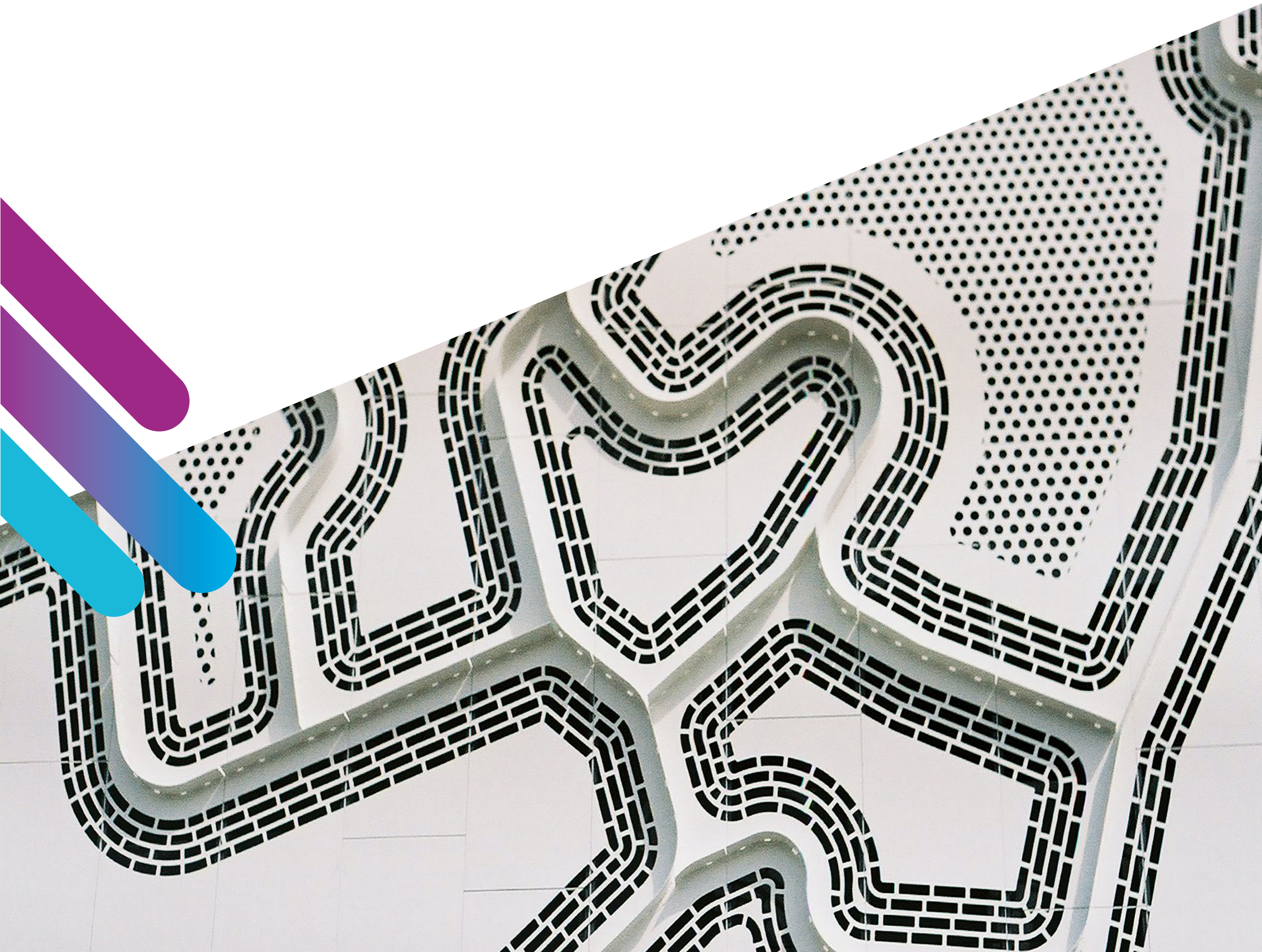


Figure 3. Phases of modelling steps according to the effort needed (share of workload)

Generally, a model is always a limited and simplified interpretation of reality, so its analysis requires interpretation. It is difficult for a transport model to comprehensively include all the factors that impact mobility decisions. It is, therefore, necessary to make assumptions that help reduce the complexity of the model. The degree of assumptions varies according to the available information and influences the valid interpretation of the model results. It is essential to justify the assumptions and constantly question them to improve them.



Why to develop a transport model?

A transport model's primary goal is to figure out a virtual predictive situation different from the existing one and to estimate its effects on mobility usage. It aims to support decision-making regarding the development of transport infrastructures or reorganisation of transport services.

A transport model enables the assessment of the adequation of a transport supply scenario in a specific socioeconomic context and, therefore, the design of a public transport network that suits a city's mobility needs, integrating foreseen urban developments. More specifically, a transport demand model allows transport planners to find the best compromise between the satisfaction of the transport demand and investments to be realised both on infrastructure and services.

On the one hand, transport models can offer a broad range of information, from strategic indicators on large territories to very local perspectives. As part of a SUMP elaboration process, transport models enable us to assess the modal split in future situations, and therefore GHG emissions, as well as the GHG emissions reduction to achieve if an alternative scenario is adopted instead of a "business as usual" scenario.

On the other hand, transport models present limits, as they are designed and built for specific needs, questioning, and methodological assumptions. Therefore, these tools become irrelevant when dealing with fields or scales outside the initial scope. Limitations are relevant when the model needs influencing variables not considered in the design (e.g., individual environmental concerns). Similarly, the model's reliability may be limited when simulating extreme conditions (unprecedented fuel cost, for example) that would disrupt documented behaviours.

One common mistake when using a model is to try to find answers for which it has not been designed. More generally, according to surveys, demand models rely on the knowledge of current mobility patterns. Although these patterns are reproduced to a different extent, depending on the type of implemented algorithms, the predictive power of a transport model is still limited in assessing highly disruptive situations (for example, brutal exodus or massive developments like a new city or an MRT project likely to reorganise mobility patterns in a significant extent).

The modelling approach can be simplified at the SUMP level to save resources and therefore allow for an upgraded data collection program. Simplification may result in more profitability in the context of scarce data while limiting the ability to set a quantified target for the SUMP. A trade-off should be found based on considerations developed in the next chapter.

- Incoming information (data quality and quantity).
- Expected answers (detailed/strategic data).
- Territory scales that should be considered.
- Foreseen changes and disruptive character of the future situation to be assessed;
- Relevance and limits of underlying assumptions.

What kind of model is best suited for MobiliseYourCity SUMPs?

Macrosimulation models

Four types of macrosimulation models can be distinguished, which are detailed hereafter. **Considering the overall objectives of demand forecast, as part of the elaboration of a SUMP, and the context usually at stake when intervening in a developing city, the most used ones are the simplified and the four-steps model.** While following different purposes, they both allow to:

- Support decision-making over the long term.
- Assess significant changes in mobility patterns that are likely to happen considering the time scale, the maturity of the studied territory (e.g., the tendency of the urban structure or the mobility system to evolve throughout time) and the objectives intended by the developing scenarios.

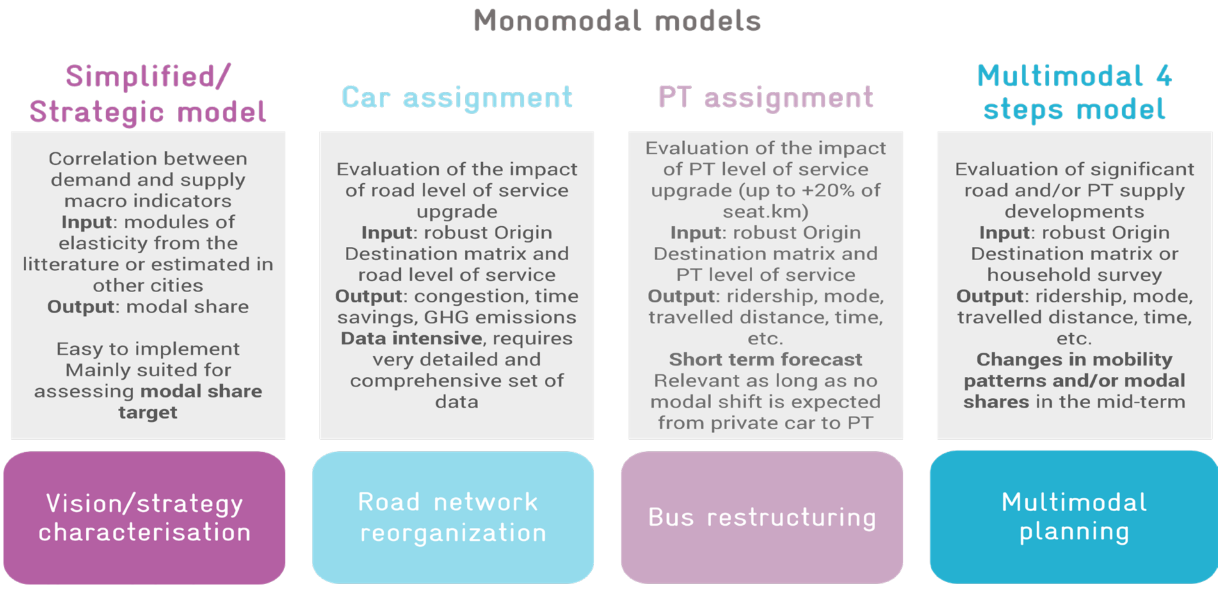


Figure 4. Macrosimulation model types

Even though the simplified model and the four steps model are both relevant, they do not provide the same results nor the same level of confidence:

- A **simplified model** allows setting a target modal share for the future, although in an indicative way. Indeed, results cannot be considered accurate forecast[1] trips over transport modes or services, thus providing the basis for setting quantified targets in the short, mid and long term.
- A **four-steps model** is critical to properly evaluating transport projects in the implementation phase. Developed along the SUMP elaboration, it thus figures a deliverable that can later support local authorities in their day-to-day planning activities, including ex-ante evaluation.

[1] This observation is well documented in the literature, including in Modelling Transport (Ortuzar, Willumsen, 2011): "Sketch planning techniques seem to offer advantages in terms of simplicity, fast response and low data requirements. However, very often they rely too heavily on the transfer of relationships and parameters from one context to another. This detracts from the analysis unless it is performed only as an initial coarse sketch to select possible solutions for more detailed con-sideration."

It is worth highlighting that **designing an optimal scenario and setting the target for the SUMP cannot rely strictly on the model outputs, and it requires a critical sense and a qualitative approach, regardless of the model used.** Typically, macroscopic models are not well adapted to determine a target modal share for walking and cycling, meaning that qualitative adjustment may be needed to correctly reflect the priority set for that mode.

Simplified models

Simplified models intend to assess modal shares consistently with macro indicators. They may be preferred under the following circumstances:

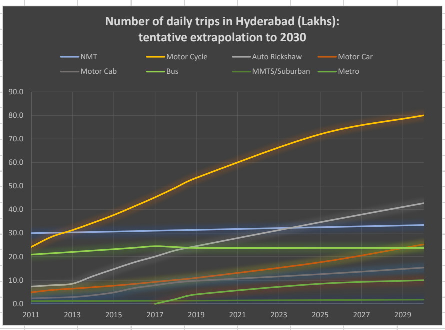
- Very poor or limited data is available, making data production a primal need
- Limited change in the future public transport supply (restructuring of existing modes)
- A highly disruptive situation is expected in the future, likely to strongly limit the capacity of the model to predict the transport demand
- There is no major project to be evaluated during the implementation phase or limited interest from the city to internalise modelling capacities.

Two kinds of simplified models can be distinguished – starting with the simplest:

- **Sketch planning methods rely on simplified relationships between demand and supply** and steady formulas based on macro indicators (fuel price, car ownership, GDP, mobility rate).
- **Incremental elasticity methods** rely on simplified relations between demand and supply variation. Related formulas consider an elasticity coefficient extracted from the literature[2] or estimated in other cities.

In both cases, results shall be considered carefully, as simplified models are more approximate than any other ones. Indeed, they reflect relations observed in other cities instead of locally grounded.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2025	2030	
Population (Lakhs) GHMC	68.1	69.9	71.7	73.6	75.5	77.5	79.6	81.7	83.8	98	111.5	
Vehicles (Lakhs)												
Motor Cycle	21.1	24.91	27.36	30.1	32.97	36.22	39.55	43.17	46.79	63.0	70	
Auto Rickshaw	0.91	0.98	1.06	1.46	1.83	2.19	2.49	2.82	3.04	4.3	5.3	
Motor Car	4.81	5.8	6.37	6.98	7.62	8.36	9.2	10.05	10.9	17.5	25	
Motor Cab	0.33	0.37	0.41	0.52	0.69	0.96	1.13	1.3	1.4	1.8	2.2	
Bus	0.22	0.24	0.27	0.28	0.29	0.3	0.31	0.32	0.35			
Goods	1.48	1.62	1.78	2.06	2.26	2.54	2.86	3.3	3.56			
Others	0.86	0.92	0.98	1.49	1.8	2.19	2.71	3.31	3.58			
Total	29.71	34.84	38.23	42.89	47.46	52.76	58.25	64.27	69.62			
Daily individual mobility GHMC (2011: CTS 6-13~6-14)												
NMT	0.44	0.43	0.42	0.41	0.41	0.40	0.39	0.38	0.37	0.33	0.30	
Motor Cycle	0.35	0.41	0.44	0.47	0.50	0.53	0.57	0.60	0.64	0.73	0.72	
Auto Rickshaw	0.11	0.11	0.12	0.16	0.20	0.23	0.25	0.28	0.29	0.35	0.38	
Motor Car	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.12	0.13	0.18	0.23	
Motor Cab	0.03	0.04	0.04	0.05	0.06	0.09	0.10	0.11	0.12	0.13	0.14	
Bus	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.29	0.28	0.24	0.21	
MMTS/Suburban	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
Metro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.09	0.09	
Total	1.33	1.40	1.43	1.51	1.59	1.68	1.75	1.83	1.90	2.07	2.08	
Number of daily trips (Lakhs)												
NMT	30.0	30.1	30.3	30.5	30.6	30.8	31.0	31.2	31.4	32.5	33.4	14%
Motor Cycle	24.1	28.5	31.3	34.4	37.7	41.4	45.2	49.4	53.5	72.0	80.0	34%
Auto Rickshaw	7.3	7.9	8.5	11.8	14.7	17.6	20.1	22.7	24.5	34.7	42.7	18%
Motor Car	4.8	5.8	6.4	7.0	7.7	8.4	9.3	10.1	11.0	17.6	25.2	11%
Motor Cab	2.3	2.6	2.9	3.6	4.8	6.7	7.9	9.1	9.8	12.6	15.4	7%
Bus	20.9	21.5	22.0	22.6	23.2	23.8	24.4	24.1	23.7	23.7	23.7	10%
MMTS/Suburban	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.6	1.8	1%
Metro							0.0	2.0	4.0	8.5	10.0	4%
Total	90.6	97.5	102.6	111.1	120.0	130.0	139.2	149.9	159.2	203.2	232.2	100%
	38.6	44.8	49.1	56.8	64.9	74.2	82.4	91.3	98.8	136.9	163.3	165%



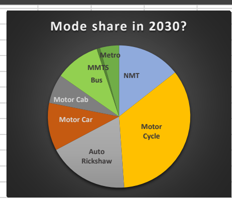


Figure 5. Hyderabad Public transport corridor supply - Source: Suez Consulting for AFD

[2] Modelling Transport (Ortuzar, Willumsen, 2011) recommends the transportation elasticities collection proposed by the Victoria Transport Policy Institute (www.vtpi.org) compiled by Todd Litman (http://www.vtpi.org/tdm/tdm11.htm).

The four-steps models

The four-step model is one of the most widely used in traditional urban transport planning and is an excellent tool to diagnose the current mobility situation and assess how possible interventions could influence citizens' decisions in the future. Four-step models intend to measure the impacts and benefits of one or multiple large-scale urban or transport projects, simulating the interactions between demand and supply systems.

Using a four-step model for the SUMP purpose can be contemplated if collecting quantitative mobility data is not the first necessity – e.g., if databases are available and a household survey or an intensive origin-destination survey are affordable. Under these circumstances, the model would provide for most of the SUMP requirements.

In practice, this model relies on the assumption that travels are made after a chain of decisions: 1) whether the individual travels or not; 2) if they travel, the destination; 3) the modal choice to reach the destination; and finally, 4) by which route. The decision process includes the 4 corresponding steps, and they are further detailed hereafter.

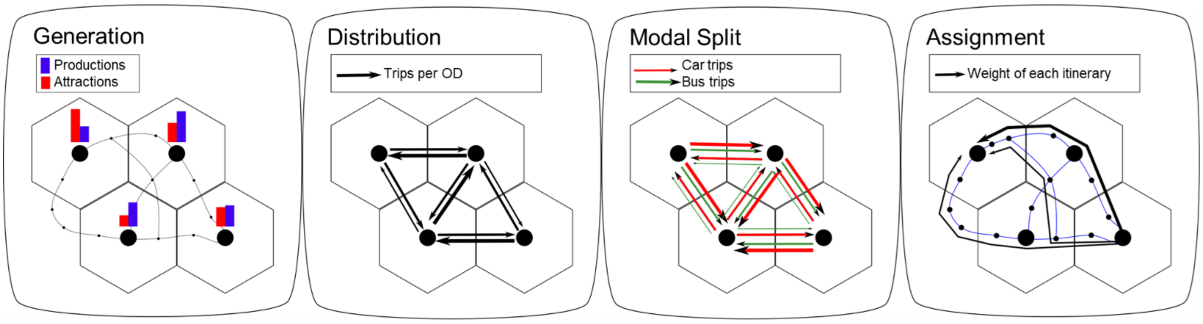


Figure 6. Classical structure of the four-steps model

1. Trip Generation:

What is the mobile population? How much does this population travel? Where is it likely to travel?

This step uses information on the territorial distribution of housing centres, main economic activities, and other socioeconomic and demographic parameters to estimate the volumes of trips emitted and received for each zone of the area of interest. Zoning is a method that is part of the preparation for the generation step and depends on existing data from previous transport models or other geostatistical units in each country. Each delimited zone is called Traffic Analysis Zones (TAZ), a homogeneous area in socioeconomic and territorial terms. More densely populated areas generate more trips, with the number of trips being a function of population.

2. Trip distribution:

Where are people going to go? What are the resulting flows from each zone to each other?

Here, the model matches each trip's origin and destination. The trip distribution aims to carry out the spatial distribution between the origins and destinations of the trips identified in the previous stage and, thus, to define the origin-destination pairs of trips in the study area. The mathematical process starts by estimating the impedances or resistances to everything that opposes the choice of a destination. This model obtains the origin/destination matrix or desire lines. Traditionally, gravity distribution models are popular, considering that the desire to travel between two zones grows according to the number of trips generated in each zone and decreases as travel costs increase.

3. Modal split:

How are people likely to travel? What mode of transport do they choose?

This step determines the repartition of trips among the different modes simulated. The modal choice follows a model in which travellers behave to reduce transport costs and maximise utility according to socioeconomic characteristics. In this model, the costs associated with using each mode come into play: public transport fares, fuel and parking costs, among others. Travel time is usually a determinant variable in utility functions, knowing that each mode of transport has an associated average speed and each mode of transportation has a different travel time for a certain distance.

4. Route assignment:

Which route or line are they to choose?

This step allocates each origin-destination trip to the network of a mode. Using the modelled road network, it aims to show the trips' spatial pathways and obtain the volumes and loads for each corridor. Based on the modal choice, available infrastructure, travel times, congestion, public transport services, and other parameters, the model assigns trips to a specific route according to their origin and destination. This step allows seeing the most used corridors and the users' preferences when choosing their route.

The four-step models can cover various modelling tools, depending on the steps implemented and the algorithms selected for each step. The approach for designing the model considers the following parameters:

- The objectives set for the model concerning the questions to be addressed
- The nature and quality of input data
- The magnitude of expected changes to be assessed by the model

Depending on these parameters, the modeller should set the type of algorithm that is more ade-quate for each step among three categories:

- Homogeneous (a.k.a proportional)
- Incremental
- Explicit

It is important to note that the two last parameters mentioned above are somehow related. If the future brings disruptive situations, the model will likely rely on predictive algorithms (based on explicative relationships between demand and supply) instead of input data that reflect the current mobility pattern. Conversely, the choice of one algorithm against another may come out of necessity, e.g., data quality/availability driven rather than relevancy, according to the context.

In the next chapter, combinations of algorithms are suggested according to the objectives pursued. The options for implementing each step of the four-steps model are detailed hereafter.

Figure 7 illustrates the relevance of each type of algorithm for the first three modelling steps (generation to modal split) and explicates under which circumstances an algorithm should be preferred.

	Homogeneous or proportional	Incremental	Explicit
Generation	**In case of poor knowledge of pop./jobs and mobility determinants** (e.g. ability to reproduce trips emissions/attractions through correlation)	**In case of average knowledge of pop./jobs and mobility determinants** Proportional to the variation of socioeconomic variables, according to the household survey	**In case of good knowledge of pop./jobs and mobility determinants** Proportional against linear regressions based on the household survey results
Distribution	Steady or proportional to the population growth, possibly per zone	Proportional to the level of service **Allow to take into consideration travelling time increase**	Based on a combined assessment of opportunities and distance (independent from the existing situation)
Modal split	Derived from relation between LOS variation and modal shift, according to household survey or exogeneous data **Preserve the quality of original data** **More accurate on baseline situation**	Derived from relation between LOS variation and modal shift, according to household survey or exogeneous data **Preserve the quality of original data** **More accurate on baseline situation**	Simulation of interactions between demand & supply systems according to standard behavioural law **More calibration effort** **Higher predictive power**

Figure 7. Rationale for using one algorithm or another, according to steps
**LOS: Levels of service*

Some recommendations are formulated at this stage regarding the choice of algorithm and the way to combine them:

- The less uniform the expected changes are (regarding urban mobility patterns and developments), the less valid the homogeneous or proportional approach is.
- Algorithms shall be consistent with one another: if one step is not incremental, the following steps should not be incremental either.

Regarding the fourth step (route assignment), different approaches exist, although they do not fall into the same categories as above (see Figure 8).

	PT assignment	Car assignment
Least advanced	Shorter path according to headway **Well suited for urban scale** Multi path To support finer modal split, with specific modal penalties	Linear regression according to the distance as the crow flies, based on GPS tracks or household surveys
	Optimal strategy, according to "cumulated headway" **Relevant in a context of high competition, with various lines running along a backbone axis**	Free assignment according to average speed **Sensitive to infrastructure/supply development**
Most advanced	With capacity constraint **Relevant in a context presenting an efficient and congested PT service**	With capacity constraint, based on speed flow rate curve and no load speed **Sensitive to capacity upgrade**

Figure 8. Approaches for the assignment module, respectively for public transport and private cars, from the least to the most advanced option

Commercial tool vs open-source tool?

Transport models can be built with commercial or free software or in a mixed way. Indeed, some stages of the models can be built with free software and others with commercial software. **Determinants for choice rely on existing capacities and target use cases for the long term** – execution vs adaptation and maintenance – that also define the need for external maintenance. Although open-source tools have potential, as they allow for further development or adjustment of algorithms as needed, their maintenance requires advanced programming skills.

Cost remains an argument that favours open-source models to a large extent. Open-source solutions are available at 10 to 30% of the costs of commercial solutions (considering an acquisition, use and maintenance). As for development time and cost, there is no significant advantage of one solution or another, considering similar qualifications of developers in respective techniques.

	Open-source model	Commercial model
Capacity & use case	Limited programming skills & execution only Advanced programming skills & use and maintenance	Basic programming skills & use and maintainance
Cost*	Over 10 years : about 100 000 EUR Over 30 years : about 3 000 000 EUR	Over 10 years : 300 000 – 1 000 000 EUR Over 30 years : 10 000 000 – 30 000 000 EUR
Existing solutions	Quetzal	Cube, Visum, Aimsum, Transcad, Emme

* Use and maintenance costs for a team of 20 users

Figure 9. Approaches for the assignment module, respectively for public transport and private cars, from the least to the most advanced option

Per experience, free software allows for more flexibility and can be adapted to users' needs and capacities. An advanced use (e.g., execution and full maintenance) requires solid programming skills. Their use can be an issue in contexts where local expertise is scarce, putting the model's sustainability at risk if, e.g., the person in charge leaves their position. For essential use (or execution only), open-source software can propose a much simpler interface. At the same time, there is no license to be funded, and external contributions or synergies with academics are facilitated. Besides, open-source tools may facilitate data processing and mapping, that account for more than half of the workload over the process.

Conversely, commercial software is costly, as users must purchase a license. While modelling skills are still required, the modelling program can be interpreted more efficiently, which broadens the pool of technical resources to use and maintain the model, thus enhancing its continuity over time.

In both cases, modelling knowledge retention is an issue to address by creating a dedicated community of practice committed to regular capacity building and capitalisation, besides common principles for human resource management.

Some examples of commercial and open-source model-ling tool user interfaces are presented in Figures 9 and 10. Commercial tools commonly offer a graphical and advanced interface that can get complex due to the number of menus and parameters. On the other hand, open-source models tend to have less user-friendly interfaces. However, it can be tailored to users' needs and capacities, adapting to the complexity of the options proposed. Logically, limiting the complexity of the user interface also tends to limit the potential of the modelling tool.

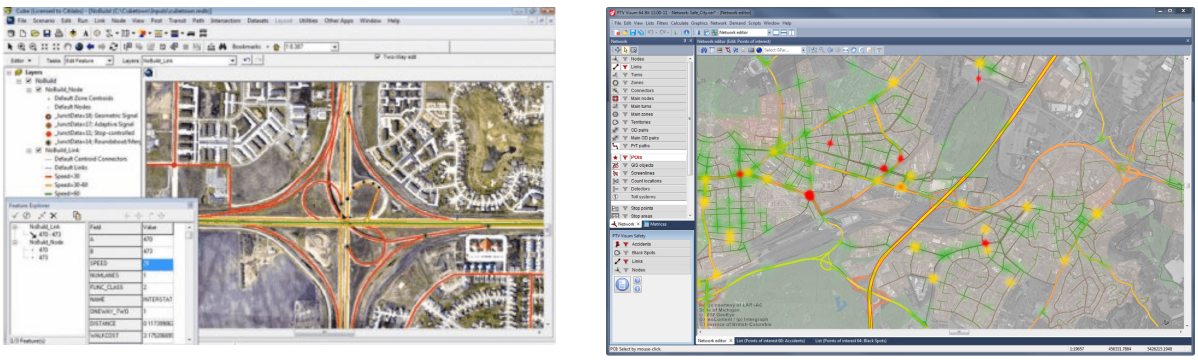


Figure 10. Interface of commercial tools implementing four steps model (left: CUBE, right: VISUM)

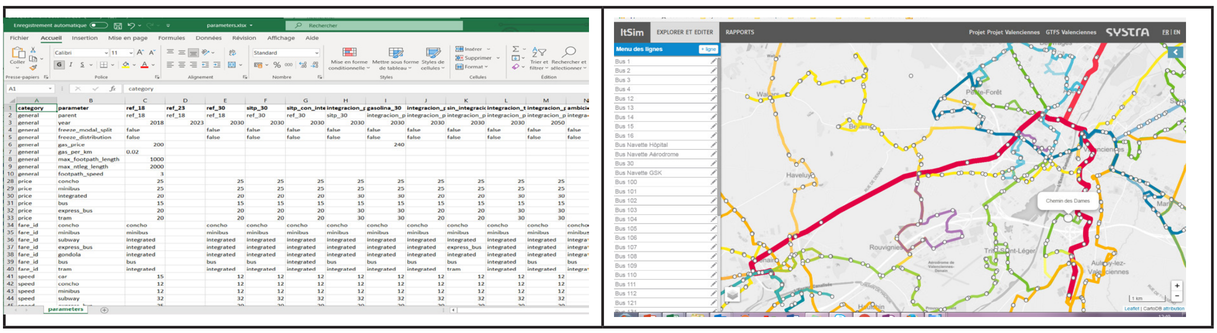


Figure 11. Interface of an open-source tool implementing four steps model (Quetzal, left: scenario settings in excel, right: PT network settings)

How to determine the best type of model?

On a practical level, **the modelling approach should be defined according to the local context, capacities, and pursued objectives**, as detailed in Figure 9. Thus, the SUMP team may opt for a simplified/strategic or four-step model. Technical support is likely needed to weigh the different arguments without a local modelling expert.

	Situation where a simplified model can be favored	Situation where a four steps model can be favored
Context	In cities with limited footprint/population When disruption of demographic, urban or mobility patterns are expected in the future, due to the development curb or ongoing/foreseen crisis When statistical basis are poor, with few or no mobility data available	In large and populous cities Where the urban structure and the public transport network are mature (mix of paratransit and organised services) When a comprehensive amount of data is available, including long-term statistical records
Capacities	If interest and/or scientific skills are limited locally If resources to fund a demand model license and maintenance over the long term are uncertain	When there is an interest in building modelling capacities locally, with existing capacities in modelling, programming, mathematics - among the local administration, academics, private sector If the demand model maintenance can be funded over the long term
Objectives	Formulate development strategies and perspectives, transport wise, at a very preliminary stage Set up a large and comprehensive mobility data base to fill the gap and support mobility planning	Set targets for modal shift and GHG emissions in the short, mid and long term Define and assess MRT projects with significant cost and socio-economic impacts at network scale Develop a consistent approach to design and evaluate infrastructures projects in the future Strengthen capacities and get equipped for robust analysis and evaluation processes

Figure 12. Arguments to be considered to define a modelling approach

As for cost, **a simplified model requires 10 to 15 workdays of development, whereas about 45 workdays are necessary to develop a four steps model[3]**. The latter estimation refers to the SUMP project context, where the model is developed within the scope and timeline of the SUMP itself, and limited databases are available[4]. Simplified models are not correctly maintained but updated after new surveys are implemented, for example. Conversely, four steps models require regular maintenance. Related costs vary according to the type of solution, either commercial or open source (see detail hereafter).

[3] These estimates only cover for the model development, meaning that surveys design and supervision are excluded.
[4] A full fledge four steps model, as developed in European cities, rather requires about 90 man-days.

How to develop a transport model for SUMP development?

Establishing a demand forecast model is part of the SUMP elaboration process, starting from Step 2 and running if the model is used. The development phase usually takes a couple of months and is conditioned by the implementation of the survey program and the collection of existing data.

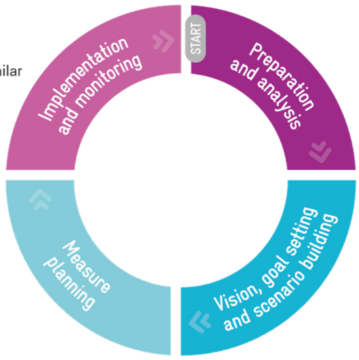
Step 10 – Manage implementation

In case demand modelling is internalised by the PTA, as part of transport projects assessment and design:

Is my model fitted for the purpose?

Is my model up-to-date?

- ✓ Model calibration (or procurement for similar services)
- ✓ Surveys design & implementation (or procurement for similar services)



Step 2 – Determine planning framework

What are the **objectives for the demand model**?

Which magnitude of change are expected to be assessed?

What seems feasible as for surveys, considering the local context?

- ✓ Modelling method
- ✓ Survey program
- ✓ Schedule

Step 3 – Analyse mobility situation

What is the ouput quality of the survey results?

What is the quality of the secondary data available?

- ✓ (Revised) modelling method

How far have we been able to **calibrate the model**?

- ✓ Calibration report

Step 4 – Build and jointly assess scenarios

What is the **ouput quality of the model** (accuracy, robustness)?

Which results can be reasonnably exploited? Under which limits?

What is the appropriate format to communicate the results?

Step 8 – Agree actions and responsibilities

How much a **demand model** is needed along the implementation phase, according to the transport projects to be assessed?

What is the strategy for the transport authority regarding modelling?

- ✓ Action sheet regarding the scope and responsibilities of the PTA
- ✓ Capacity building plan

Figure 13. Modelling milestones along the SUMP cycle

Phase 1 – Preparation and analysis

Step 2: Determine the planning framework

Modelling objective:

Define the modelling objectives and overall method, as well as derived requirements for the data collection program

The main starting issue to investigate is traffic studies' main goal and scope. What questions to answer? (e.g., traffic road volumes in specific locations? Passenger evaluation in public transport? Modal shift effects? Local neighbourhood analysis or an enormous strategical scope?) Goals and objectives must be shared and discussed with modelling experts to ensure that expected answers could later be given by the modelling tool, particularly on performance measurement. Modelling limits or state-of-art weaknesses could alter the evaluation process. Methods, processes, or tools (either modelling tools or simplified implements) must be determined accordingly.

In particular, the following aspects shall be clarified:

- **Goal settings and prioritisation** strongly influence modelling tools or methods to be deployed, the perimeter of the study and the transport modes to include and determine whether existing data are available to complete modelling tasks and scenario evaluation. This point feeds the following complementary data collection considerations (see the table hereafter).

- **Defining criteria and indicators** should consider against the modelling method. The chosen modelling tool or method should be able to support the evaluation of the indicators set in Step 5 - Develop vision and objectives with stakeholders. Conversely, criteria and indicator choices should fit with the possibilities offered by the modelling process. In other words, even if goal settings and their needed evaluation drive criteria and indicators, they must be measurable and evaluable.

Regarding the latter, it is worth mentioning that among the MobiliseYourCity core indicators (see chapter 2.3), three are meant to be estimated for future time horizon thanks to the demand model outputs: transport-related GHG emissions, air quality, the modal share of non-motorised transport and public transport. Pollutant emissions calculation is based on vehicle kilometres per mode or type of vehicle, whereas the number of trips per mode determines the modal share.

More specifically, modelling experts should assess the following points, although they may be further specified throughout Step 3 (Analyse mobility situation):

- **The geographical area** on which traffic modelling could be deployed, considering that this area should be larger than the territory concerned by the SUMP action. The assumption is that trips outside the boundaries of this area are not affected by the SUMP project. This choice is dominant since it defines the SUMP influence on travelling habits.

- **The zonal fineness** represents transport demand to find the appropriate balance between geographical demand precision (more zones for better precision) and model complexity (less complexity with fewer zones). This first choice is primarily influenced by the goal and scope of the modelling, as described above.

- **Transportation modes** must be considered among private transport, public transport, walking, cycling, and freight transport. This point defines the stakeholders to consider and the scope of the data to gather.

The detailed work plan considers these matters, including the survey program designed to match the modelling requirements. In addition, the will of local authorities to be trained to use the model may depend on the general objectives. In every case, a capacity building program should be tailored to the capacity of the personnel and integrated into the work plan, jointly with a capacity assessment.

If a four-step model is retained as the most suitable option, Figure 13 can be used to guide the transport modeller in the survey programme design according to the objectives set for the demand model.

Demand model objectives or expected function	Derived requirements regarding input data
Conduct a synthetical analysis of the transport supply	Public Transport level of service (LOS): collect headways, routes and stops Road level of service: collect speeds and capacities per road

Demand model objectives or expected function	Derived requirements regarding input data
Conduct a synthetical analysis of the forecast demand (considering future urban developments)	Household survey, enabling to compute mobility rate and sensibility to distance[5] Inventory of significative urban projects (location and number of expected housing and households)
Assess modal shift induced by a new transport solution according to current patterns	PT and road level of service Survey enabling to determine the relationship between demand and supply: Existing transport mode: household survey Introduction of a new transport mode: state preference survey[6]
Assess the demand potential on a given corridor, relevant mode, and preliminary CAPEX	Household surveys, counts, visual occupation survey (for at-grade PT modes) and boarding/alighting collected through the ticketing system (for underground/elevated PT modes) Options as an alternative -and in replacement – to the visual occupation survey if the corridor was identified in early stages: OD surveys and boarding/alighting as part of the PT LOS collection OD surveys, in case a limited number of corridors is identified OD surveys and boarding/alighting collected through the ticketing system
Determine adequate PT LOS and refined CAPEX/OPEX (in case one main corridor is identified since early stages)	Combination of household surveys, counts and robust OD surveys on the referred corridor OR Intensive OD survey on the corridor along the target periods
Determine adequate road LOS and refined CAPEX/OPEX[7]	Road supply: speed flow rate curve Road demand: road counts all day long with 10% precision on main roads
Optimise the operation design, typically for a bus (for example, shift from an OD scheme to a trunk/feeder scheme)	OD surveys over the whole network
Evaluate integrated fares and the need for public subsidies[8]	PT LOS collection, including current far policy Stated preferences focused on the evaluation of the value of time, thus proposing budget-time scenarios[9]

Table 1. Guidance for designing survey program according to the demand model objectives

[5] Also refer to chapter 1.4.1. According to the CEREMA method, a minimum sample of about 1% of the number of households is commonly considered, with at least 70 households and 160 persons to be surveyed per zone

[6] State preference surveys aim to quantify the sensitivity of transport users to certain criteria, generally price, time or transport mode. It is particularly useful to calibrate the modal split module of a demand model, determine the value of time or the willingness to pay. To do so, respondents are asked about their preference, considering different options that correspond to a fictional trip.

[7] Not so relevant as part of a SUMP, unless for a punctual infrastructure having an influence over the whole perimeter (typically a bridge standing as bottleneck between two parts of the city.

[8] Excluding the modelling of the evolution of car ownership among the population

[9] Although household surveys describe revealed preferences, they do not allow to know about available alternatives for the same trips.

Step 3: Analyse the mobility situation

Modelling objective:

Adapt the modelling method to the output quality of the collected data before building the model.

Once the survey program has been implemented and the secondary data revised, the transport modeller should revise the modelling method initially contemplated, according to the output quality of the available data, and assure consistency.

As a complement to the table previously introduced, Figure 14 proposes relevant combinations of algorithms corresponding to the demand model objectives or expected function (in the left column). The objectives that are the closest to what SUMP requires for analysis are the following:

- Assess modal shift induced by a new transport solution according to current patterns.
- Assess the demand potential on a given corridor, relevant mode and preliminary CAPEX.

Demand model objectives or expected function	Relevant combination of algorithms			
	Generation	Distribution	Modal split	Assignment
Conduct a synthetical analysis of the transport supply	None	None	None	PT only or PT & road assignment
Conduct a synthetical analysis of the forecast demand (considering future urban developments)	Incremental or proportional	Explicit	None or homogeneous if mobility patterns are kept similar	None (focus on mobility needs)
Assess modal shift induced by a new transport solution according to current patterns	Not necessary or marginal	Not necessary or marginal	Explicit (calibrated)	Assignment sensitive to the supply variation to be assessed
Assess the demand potential on a given corridor, relevant mode and preliminary CAPEX	Not necessary or marginal unless the project is directly related to urban developments	Not necessary or marginal	None or incremental if focusing on volumes rather than variations	PT assignment

Demand model objectives or expected function	Relevant combination of algorithms			
	Generation	Distribution	Modal split	Assignment
Determine adequate PT LOS and refined CAPEX/ OPEX (in case one main corridor is identified since early stages)	Not necessary or marginal unless the project is directly related to urban developments	Not necessary or marginal	None or incremental if focusing on volumes rather than variations	PT assignment
Determine adequate road LOS and refined CAPEX/ OPEX[10]	Use of the car matrix (can be based on a household survey, possibly adjusted with counting)	Use of the car matrix (can be based on a household survey, possibly adjusted with counting)	None	Car assignment with capacity constraint
Optimise the operation design, typically for a bus (for example, shift from an OD scheme to a trunk/ feeder scheme)	None	None	None	Assignment with optimal strategy
Evaluate integrated fares and the need for public subsidies[11]	Use of all modes' matrix (can be based on household survey)	Use of all modes' matrix (can be based on household survey)	At least incremental, allowing reversible shift	Assignment sensitive to fares variation

Table 2. Guidance for designing the demand model according to its objectives

[10] Not so relevant as part of a SUMP, unless for a punctual infrastructure having an influence over the whole perimeter (typically a bridge standing as bottleneck between two parts of the city.

[11] Excluding the modelling of the evolution of car ownership among the population

Phase 2 – Strategy development

Step 4: Build and jointly assess scenarios

Modelling objective:

Format modelling results to properly support decision-making

The projected demand is a crucial input for elaborating the development scenario, as it allows the identification of main corridors. At this point, it shall be noted that the demand model primarily serves to design the structuring network and propose a relevant hierarchy for the urban transport services, with a range for corresponding levels of service (e.g., headway, speed, fare). Measures affecting the other component of the mobility system are likely to be formulated and evaluated by other means.

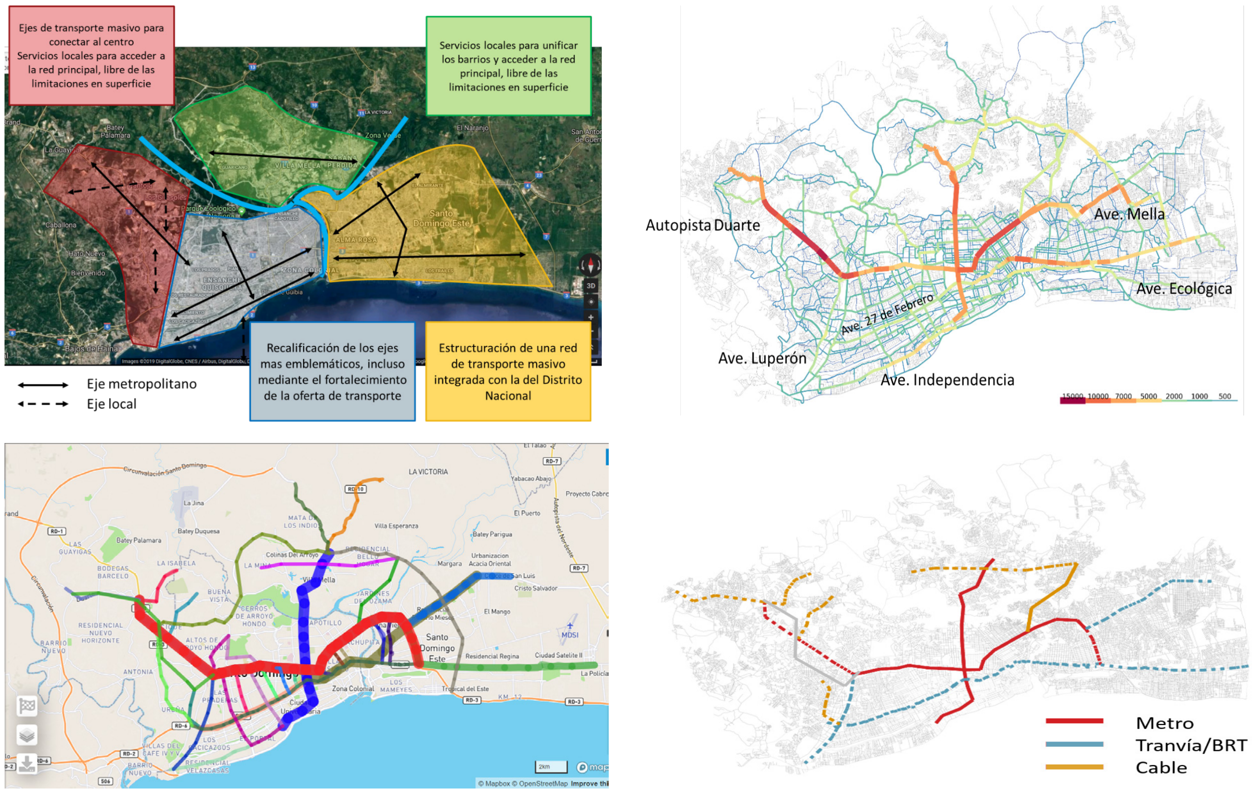


Figure 14. Scenarios building approach in the SUMP of Santo Domingo – from top left to bottom right, clockwise: mobility needs per territory, projected demand, structuring corridors identified, tentative scenario

Action	Evaluation principle	Demand	Economic	Environment
Development of a school transport service	Not evaluated, for these trips are not significant (2% del total diario)	✗	✗	✗
Enhancement of internal connectivity (turn non transitable streets pedestrian)	Sensibility test to assess the modal shift towards walking OR qualitative evaluation through benchmarking	✗	✗	✓
Design an integrated fare policy	Update of levels of service as part of the demand forecast model	✓	✓	✓
Design a social fare policy	Opportunity analisis at this stage	✗	✓	✗
Set a virtuous tax system in terms of urbanism and transport consistency	Qualitative evaluation through benchmarking	✗	✓	✗

Table 3. Evaluation rules for accessibility measures (extract) in the SUMP of Santo Domingo

The evaluation and comparison of scenarios are critical steps in the modelling process. At this point, the model results are disclosed to the stakeholders. Communicating model results requires cautiousness since the underlying mechanisms and calculation complexity can provide inconsistent conclusions. An unimportant but unexplained result can ruin the model's confidence among partners or stakeholders, even if significant results are solid. Focusing on essential and relevant results related to goals and objectives and providing simple and didactic deliverables are critical success factors in the modelling process.

Especially a few principles must be followed when reporting and communicating the results:

- Raw outputs from simulations are always, to some extent, biased by the data and assumptions taken when establishing the model. Consequently, for robust results, it is better to use the outputs comparatively between the simulated scenarios (BAU scenario vs Project option A, Project option A vs Project option B). Raw results should be used with caution.
- Beyond the results obtained from the simulation, an important point when communicating the results is to maintain the model's confidence among the stakeholders. To this end, it's better to provide simple and didactic deliverables focused on essential and relevant results related to the objectives. The stakeholders might otherwise focus on an unimportant unexplained result that ruins the confidence in the more robust and relevant results, e.g. when presenting a map of trip flows from a macroscopic model in which the stakeholders might focus on an incredible value for a very local link rather than the flows from the larger capacity road for which the model was designed.
- Provide comparative elements that put the results into perspective. Evolution rates can be hard to analyse if the public is unaware of the span and sensitivity of related indicators. Benchmarking of SUMP results in other cities may help to appreciate the actual performance of the evaluated scenarios.

For each simulation taken, the process, input data, and assumptions are exhaustively justified and documented to allow for a later review. This report can be produced outside of a feasibility study or a cost-benefit analysis report for better readability.

Phase 3 – Measure planning

Step 8: Agree on actions and responsibilities

Modelling objective:

Determine the needs for modelling resources and capacity building along with implementation, according to the planned transport projects

While considering the scope and responsibilities of the transport authority, jointly with the resources needed along the implementation of the SUMP, the modelling topic is likely to come up. Indeed, the transport projects contemplated within the SUMP will be further studied and evaluated in the following stages. A strategy shall be defined according to the model type developed to support the SUMP elaboration and the actual content of the action plan:

- If a simplified model has been used in previous steps, a four-step model may be needed, which leads to either building modelling capacities (internalisation) or getting external support (externalisation). The previous chapters should help determine the modelling method and the type of tool, either commercial or open source, that best fits with the local context.
- In case a four-step model has been used in previous steps: it is crucial to identify the gaps to be filled regarding:
  - » The model itself – adequation of the modelling tool to perform projects evaluation and derived needs for an upgrade
  - » Local capacities to use and maintain the model and derived needs for capacity building

Phase 4 – Implementation and monitoring

Step 10: Manage implementation

Modelling objective:

Adopt the modelling approach to punctual projects or needs and plan for a model update or upgrade

During the implementation phase, the same questions mentioned above may create a punctual need to design and evaluate transport projects (see detail hereafter). In particular:

- Input data may need more accuracy and up-to-date to address specific questions referring to one given corridor.
- Zoning may appear inappropriate for analysing the demand at the station/stop level.
- Additional calibration of the model may be needed.

The adequation of capacities and resources (e.g., modelling tool, available surveys) should be continuously reconsidered to plan for updates or upgrades.

Figure 17 intends to provide some general guidance on the type of measure for which demand modelling with a macroscopic four steps model is relevant, based on the considerations presented in this document. In practice, the relevance of the demand model to forecast demand or evaluate a given project should be further considered according to:

- The model design, input data or parameter, responding to the question: "Is the model sensitive to the expected impact of my project?". Typically, a model that does not integrate capacity constraint is not suited for evaluating the opportunity to improve the capacity of an MRT line unless it consists in increasing the headway, which directly impacts the assignment of the demand in a classical four steps model, and therefore the attractivity of the line.
- The representativity of the target demands the surveys used to develop the model. For instance, a demand model cannot forecast the demand for cycle lanes if the number of trips made by bike in the household survey is insignificant. More broadly, introducing a new mode requires assessing users' perception of that mode (thanks to stated preferences or qualitative surveys) to qualify its attractivity besides the proposed level of service. Some structural factors might be at stake that cannot be caught by a model (one's self-confidence in riding a bike, sensitivity to promiscuity, and perception of elevated or underground transport modes).

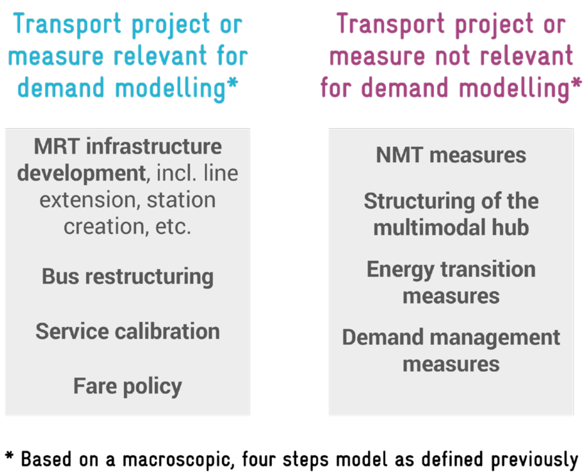


Figure 15. Transport project or measure that can be assessed thanks to a macroscopic four steps model

Main takeaways

- A transport model relies on existing knowledge of the transport supply, the transport demand and how the two interact (e.g., users' preference according to mode, price and travelling time). Based on this relation, the model enables the assessing the adequation of a transport supply scenario in a specific socioeconomic context.

- A transport model helps design a public transport network that suits the mobility need of a city, integrating foreseen urban developments. It thus allows transport planners to find the best compromise between the satisfaction of the transport demand and investments to be realised both in infrastructure and services.

- A transport model is always a limited and simplified interpretation of reality. The degree of assumptions varies according to the available information and the specific needs intended to be addressed. The resulting design of the model influences the valid interpretation of its results. One common mistake when using models is to try to find answers for which it has not been designed.

- As part of the elaboration of a SUMP and the context usually at stake when intervening in a developing city, the adequate transport models are the simplified and the four-steps models. A simplified model allows for setting an indicative target modal share for the future. On the other hand, a four steps model enables the set of quantified targets in the short, mid, and long term regarding modal share and other core indicators such as GHG emissions cut.

- The modelling approach should be defined according to the local context, capacities, and pursued objectives. In a context with very little data available, a lack of modelling or programming skills and limited ambitions for the transport model, a simplified approach may be privileged, thus generating savings that may benefit data collection, allowing for more surveys. In a context with a fair existing database, local capacities and appetence for modelling, a four steps model is worthwhile, as it can best support the MobiliseYourCity approach for developing SUMP, especially regarding the monitoring and evaluation phase. Besides, a four steps model is eventually needed to design transport infrastructures.

- Transport models can be built with commercial or free software or in a mixed way. Determinants for choice rely on existing capacities and target use cases for the long term – execution vs adaptation and maintenance. Open-source tools have more potential, allowing for further development or adjustment of algorithms. They can be designed for essential use, with a straightforward user interface, or advanced use, requiring advanced programming skills. Commercial software figures an intermediate solution: the graphical interface eases the interpretation of the modelling program, although modelling skills are still required.

- As for cost, open-source solutions are available at 10 to 30% of the costs of commercial solutions (considering an acquisition, use and maintenance). As for development time and cost, there is no significant advantage of one solution or another, considering similar qualifications of developers in respective techniques.

- As part of developing a SUMP, modelling milestones are as follows in Figure 18. It is important to note that designing an optimal scenario and setting a target for the SUMP cannot rely strictly on the model outputs, and it requires a critical sense and a qualitative approach, regardless of the model used.

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